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Vulnerability rating of the forests of Newfoundland to Spruce Budworm damage

A.G. Raske

Information Report N-X-239
Newfoundland Forestry Centre

87-03014/

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by A.G. Raske

INFORMATION REPORT N-X-239
1986

CANADIAN FORESTRY SERVICE
NEWFOUNDLAND FORESTRY CENTRE

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ISSN NO. 0704-7657
CAT. NO. Fo46-15/239E
ISBN NO. 0-662-15331-6

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ABSTRACT

A vulnerability rating scheme to spruce budworm, Choristoneura fumiferana (Clem.), damage has been devised for forest management units based on the abundance of host species, degree of maturity of these hosts, and average long-term climate. A vulnerability index has been calculated for each forest management unit of insular Newfoundland and the one unit delineated in Labrador. Management units on the west coast, in Labrador, and on or near the Bonavista Peninsula rated Very High; High and Moderate in central Newfoundland and on the Avalon Peninsula. No management unit rated low.

The vulnerability index was not as well correlated to damage caused by the recent spruce budworm outbreak as in Quebec, New Brunswick and Nova Scotia. Discrepancies in Newfoundland can be explained by: 1) the climatic rating for parts of the Province may not reflect the poor larval survival that often occurs in those parts; 2) the unexpected large-scale mortality of black spruce in central Newfoundland, and 3) the randomness of where massive moth flights may descend. Any vulnerability rating scheme is an estimate of the probability of damage and not a predictor of a certain future.

RÉSUMÉ

Un indice de vulnérabilité aux ravages de la tordeuse des bourgeons de l'épinette (Choristoneura fumiferana (Clem.)) applicable aux unités d'aménagement forestier a été établi à partir du nombre d'arbres hôtes, de leur degré de maturité et des conditions climatiques moyennes à long terme. L'indice de vulnérabilité de chaque unité d'aménagement de l'île de Terre-Neuve et de l'unique unité du Labrador a été calculé. Les unités d'aménagement de la côte Ouest, du Labrador, de la presqu'île Bonavista et de la région environnante avaient un indice très élevé et celles du centre de Terre-Neuve et de la presqu'île Avalon, un indice élevé et moyen. Aucune unité n'avait un indice de vulnérabilité faible.

La corrélation entre l'indice de vulnérabilité et les ravages causés par la récente épidémie de la tordeuse n'était pas aussi nette qu'au Québec, au Nouveau-Brunswick et en Nouvelle-Écosse. Les raisons suivantes peuvent expliquer les écarts constatés à Terre-Neuve: 1) la pondération des facteurs climatiques de certaines parties de la province peut ne pas refléter le faible taux de survie des larves souvent observé à ces endroits; 2) la mortalité massive et imprévue de l'épinette noire dans le centre de Terre-Neuve; et 3) l'impossibilité de savoir où frapperont les nuées de papillons. Tout indice de vulnérabilité n'est qu'une estimation des dommages probables et non pas un outil de prévision des ravages.

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ACKNOWLEDGEMENTS

The vulnerability rating system was devised by a Canadian Forestry Service committee composed of J.R. Blais (chairman), L. Archambault, D.A. MacLean, D.P. Ostaff, and myself. The forest inventory data was supplied by M. Osmond, Newfoundland Department of Forest Resources and Lands. Thanks are due to W.J. Sutton, who was my liaison with the Newfoundland Department of Forest Resources and Lands, and stimulated profitable discussions. I thank J.R. Blais, formerly with the Laurentian Forestry Centre and D.A. MacLean of the Maritime Forestry Centre for their helpful criticisms of the manuscript. Typing of the manuscript by E. Cooper and final typing by M.F. Gillingham is gratefully acknowledged.

VULNERABILITY RATING OF THE FORESTS OF NEWFOUNDLAND TO SPRUCE BUDWORM DAMAGE

by

A.G. Raske

INTRODUCTION

The spruce budworm, Choristoneura fumiferana (Clem.), periodically caused tree mortality in large regions in eastern North America. Outbreaks of this insect can destroy balsam fir, Abies balsamea (L.) Mill., stands and may cause large losses in white spruce, Picea glauca (Moench) Voss., and black spruce, Picea mariana (Mill.) B.S.P., stands. Extensive budworm damage is currently a serious forest management problem because economic wood supplies are marginal (Reed & Assoc. 1978). Faced with potential losses from a threatening budworm outbreak, the forest manager may choose to protect his crop by spraying, or to presalvage trees expected to die or to salvage dead trees after the outbreak. With current technology, spraying chemical or biological insecticides is the only consistent effective short-term method available to protect trees from budworm attack.

It would be beneficial to the forest manager if he could look ahead and estimate the probability of his forest being severely damaged by the budworm. In other words how vulnerable is his forest to spruce budworm damage. Vulnerability is defined as the probability of tree mortality resulting from a budworm attack. The concept should be distinguished from susceptibility, which refers to the probability of an

outbreak developing within the forest (MacLean 1980). A vulnerability index would benefit the forest manager by providing a forecast of which stands under his management have greater probability of being damaged.

The factors included in calculating a vulnerability index must be stable, predictable, easy to measure and responsive to insect numbers on a regional basis. Factors such as weather, or mass flights of moth change frequently therefore they were excluded. Stable factors that influence vulnerability were forest composition, age of susceptible host stands, and average long-term climate.

Past studies have been unable to relate stand characteristics to degree of budworm damage with reasonable precision. MacLean (1980) in his review of the literature concluded: "Total expected mortality from a budworm outbreak in a given stand, or the relation of mortality to stand characteristics, is not easy to predict. However, it is possible to group data from past outbreaks so as to obtain a rough estimate of mortality for mature or immature stands of the various host species." These rough estimates of expected mortality for the various stand types have been systematized into a vulnerability rating system. A working group of the Canadian Forestry Service, with representatives from Ontario, Quebec, the Maritimes and Newfoundland, developed a Vulnerability Index applicable to coniferous forests in eastern Canada.

This Vulnerability Index has been applied to the forests of New Brunswick and Nova Scotia (MacLean 1982) and of Quebec (Blais and Archambault 1982). MacLean (1982) also reviewed the literature of stand vulnerability to spruce budworm damage. This report describes the Vulnerability Index (V.I.) developed, applies it to the forests of Newfoundland and compares vulnerability ratings to the actual budworm damage sustained during the recent outbreak.

THE VULNERABILITY INDEX

The V.I. was developed to rate an area of land comparable in size to the forest management units (MU) now used in Newfoundland (Figure 1). It is not applicable to a whole province nor to a rather small land area consisting of only several stands. Calculation of the V.I. includes four components.

1) The combined average volume per ha of balsam fir and white spruce.

These two species are the most vulnerable to the spruce budworm. The volume estimate used is the total volume of fir and white spruce in all stands and not only that in fir and spruce stands. The area is the total forested area capable of producing a merchantable forest. Non-forested lands, such as agricultural lands, bogs and barrens, are excluded. The latest forest inventory, available before the outbreak, was used for these calculations (Anon. 1981).

Volumes of fir and white spruce were given the following ratings:

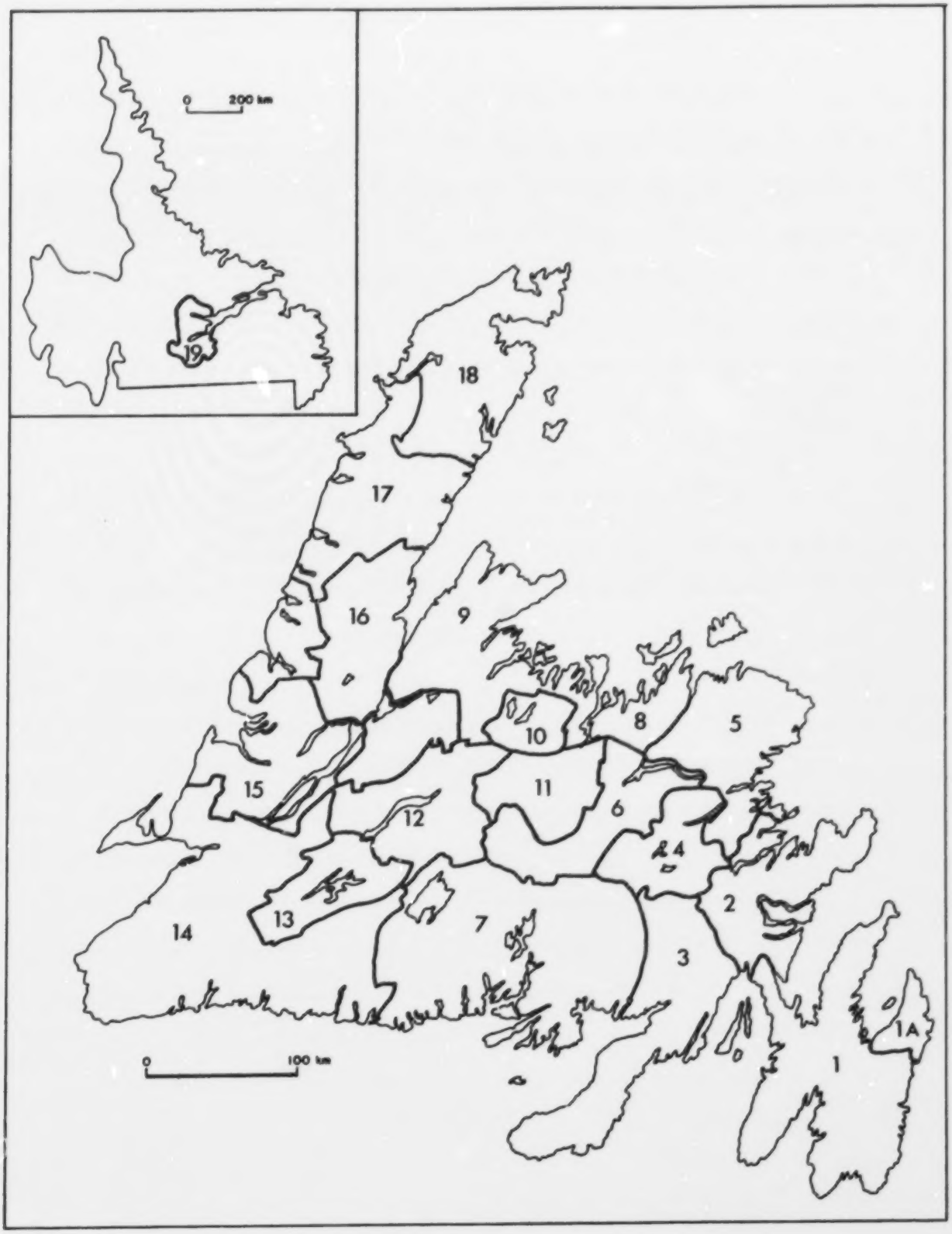

Figure 1. Forest Management Units of Newfoundland.

Combined volume of fir and white spruce (m^3/ha)	Rating
1-6	1
7-13	2
14-20	3
21-27	4
28-34	5
35-41	6
42-48	7
49-55	8
56-62	9
63+	10

2) Maturity of balsam fir. The larger the proportion of mature balsam fir the more vulnerable the stands within a management unit. Here again the latest pre-outbreak data were used, and ratings were assigned as follows:

Percent of fir older than 60 years	Rating
1-20	1
21-40	2
41+	3

3) The combined volume per ha of black spruce. As for fir, the total volume of spruce is used and the total forested land capable for producing a merchantable stand.[1] The same numerical rating is used as for balsam fir.

The amount of black spruce present can also influence budworm populations. It is unlikely that black spruce stands would maintain budworm outbreaks by themselves, because this tree species offers

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[1]In other eastern provinces the volume of red spruce, P. rubens Sarg., is included. However this species does not occur in Newfoundland.

less favourable conditions for budworm survival than fir and white spruce. However, the presence of spruce in fir areas can contribute to the severity of budworm outbreaks and therefore to the vulnerability of a management unit.

4) The average long-term climate is rated as to its suitability to budworm outbreaks. A warm-dry climate is thought to favour outbreaks. For the V.I. warm is defined as a mean annual temperature of 2.5°C or more, and dry as precipitation of 900 mm/yr or less. Other climates are termed cool and wet.

Climate	Rating
Warm-dry	8
Warm-wet	4
Cool-dry	4
Cool-wet	0

The climate rating of the majority of the management unit was taken as the rating for the whole unit.

The V.I. is then calculated as follows:

$V.I. = (FR \times MR) + SR + CR$; $SR = 0$ for $FR < 4$

where V.I. = vulnerability index
FR = fir plus white spruce volume rating
MR = maturity rating
SR = black spruce volume rating
CR = climate rating

The SR is zero unless the FR is greater than 4, because only if fir is reasonably abundant will spruce contribute towards increased vulnerability.

The vulnerability index was calculated for each of the 18 forest management units of insular Newfoundland and for the one forest management unit delineated in Labrador. The V.I.'s were then grouped into classes of vulnerability defined as follows:

< 7	=	Low
8 to 15	=	Moderate
16 to 24	=	High
> 25	=	Very high

APPLICATION OF THE VULNERABILITY INDEX TO NEWFOUNDLAND

The V.I. calculated for the various forest management units applies only to the forested lands within the unit. Therefore bogs and barren lands were not mapped. The V.I.'s were uniformly Very High for the western part of the Island, the Bonavista Peninsula and adjacent areas, and the management unit in Labrador (Figure 2, Appendix I). The forests in the central core of Newfoundland's spruce forests were rated as Moderate, as were the forests of the Burin and Avalon Peninsulas. The remainder of the management units were rated High because of the high fir content. No management unit had a Low rating because practically all of Newfoundland's forests are the northern fir-spruce type. In general, Newfoundland's forest were rated as vulnerable to budworm damage in an outbreak situation. This vulnerability is caused mainly by the abundance of susceptible host species and partly by the reasonably favorable climate for budworm development and survival.

The amount of mortality caused by an outbreak can be used to test the vulnerability rating system. Cumulative damage by the recent budworm outbreak was scattered somewhat uniformly across the Island (Figure 3) by 1983 with larger, contiguous patches of damaged stands in central Newfoundland. The larger areas of damaged stands are mostly

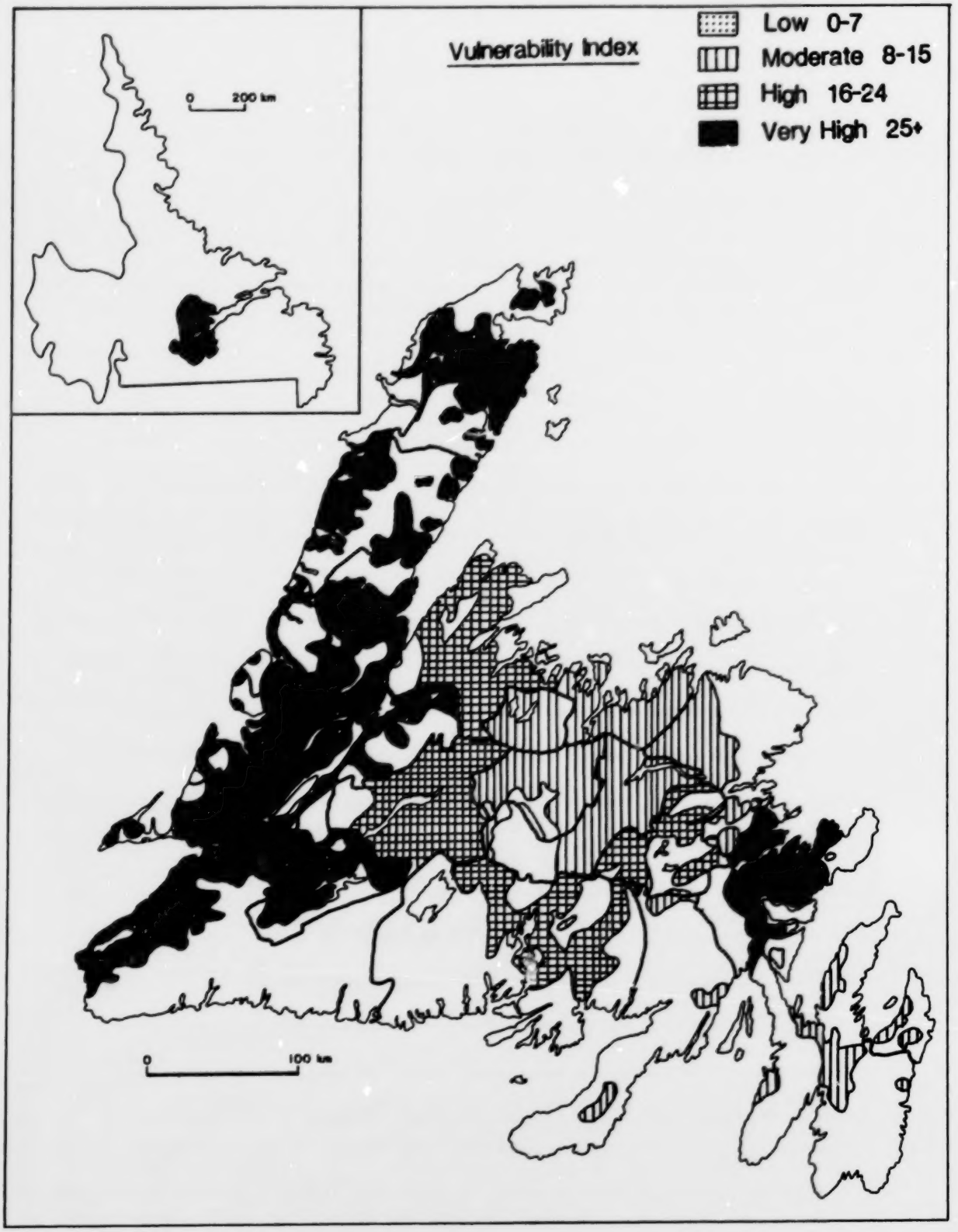

Figure 2. Vulnerability categories to spruce budworm damage of productive forest lands by Forest Management Units in Newfoundland.

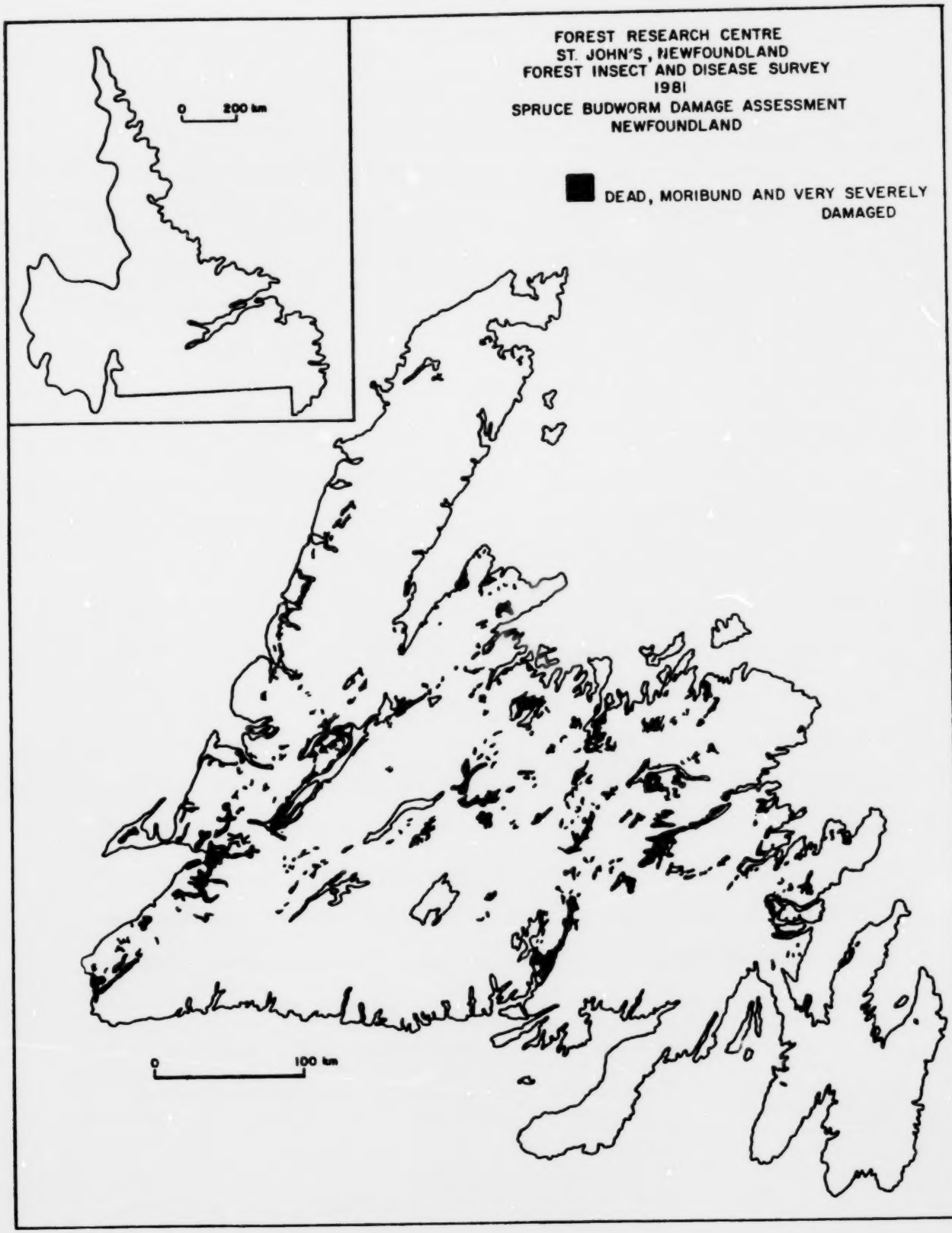

Figure 3. Areas of tree mortality caused by the spruce budworm outbreak in Newfoundland from 1972 to 1981.

black spruce stands which died in fall of 1982 and in 1983 after the budworm collapsed in most areas in 1981. This mortality was greatly influenced by secondary pests, it was unexpected and does not conform to the vulnerability based on past experience. There is partial correlation between the vulnerability based on management units and damage received (Figures 2 and 3).

There are two major areas of discrepancies: 1) There was little damage to the stands on the Northern Peninsula though they had a Very High V.I. This could be caused by the climatic rating and also by a chance phenomenon. The climatic rating chosen for eastern Canada may not reflect budworm survival in this region adequately. Budworm survival in this region is poor even though balsam fir is abundant. The chance phenomenon of moth flights will be discussed later. 2) The large amount of black spruce mortality in central Newfoundland where the V.I.'s were Moderate. Similar large-scale mortality of black spruce had not occurred before and probably was greatly aided by secondary organisms which killed black spruce that would have survived budworm damage (Raske and Sutton 1986).

The relative damage per management unit, i.e. the percent of wood volume killed by the budworm per management unit, was also not well correlated to the V.I. (Table 1). The major cause of the lack of correlation are the same as discussed. Another reason for the lack of correlation was the compounding effect of other insect damage just prior to the outbreak. Trees in a number of areas in southwestern Newfoundland had

Table 1. Living and dead softwood volume in Newfoundland in 1983‡ and proportion of living wood killed by the spruce budworm.

M.U.	Volume m^3 (x 000 000) Living fir	Dead and dying spruce and fir	% Dead wood	V.I.
1	3.18	.065	2.0	12
2	4.37	.236	5.4	25
3	1.35	0	0	12
4	1.11	.619	55.8*	17
5	1.58	.910	57.8*	14
6	2.91	2.073	71.2*	14
7	2.96	1.505	50.8*	20
8	2.00	1.280	64.0*	12
9	6.90	3.207	46.5*	20
10	.97	1.677	172.9*	12
11	1.12	1.065	95.1*	11
12	3.47	.788	22.7	16
13	2.46	.402	16.3	33
14	12.40	4.561	36.8	31
15	13.40	2.738	20.4	27
16	12.09	.407	3.4	31
17	10.26	.423	4.1	31
18	8.71	.102	1.2	31
19	12.30	.040	0.3	25

*Considerable spruce mortality included.

‡The latest tree mortality figures available by management units.

been weakened by such insects as the hemlock looper and the balsam woolly aphid, and these trees succumbed quickly when further damaged by the budworm. This damage had not occurred in the west, north of Corner Brook.

DISCUSSION

In general, correlation between the vulnerability rating and severity of spruce budworm damage for the management units in Newfoundland was not as good as in Nova Scotia, New Brunswick and Quebec. McLean (1982) reported that the V.I. values in general represented the expected vulnerability of forests in the region. The extensive spray program in effect since 1952 complicated the assessment of the V.I. because this program prevented most of the budworm damage that would have been caused in the absence of the spray. MacLean felt that discrepancies in Nova Scotia could be attributed to the outbreak not being as severe as in other areas. On the other hand, Blais and Archambault (1982) observed that the V.I. of forest units in Quebec were well correlated with damage sustained by the recent outbreak; but they also had a few discrepancies.

Some discrepancies in Newfoundland are probably best attributed to chance of where invading moth flights descend. Where they descend is largely depended upon air temperature and direction and speed of wind. These are essentially random processes, in the sense they are not dependent upon the vulnerability of the forests on the ground. Highly vulnerable stands may be missed, such as management unit 16, and less vulnerable areas may be inundated by moths. Management units in western Newfoundland are subject to moth invasion from mainland Canada (Dobesberger et al. 1968), and once a budworm population has increased to high levels they can be the source of continual massive moth flights downwind into central Newfoundland. This may explain the high populations and severe

damage in management units with lower V.I. than the west coast areas. Thus forested areas downwind from extensive fir areas may be more vulnerable than their V.I. might indicate.

Another explanation of discrepancies lies in the nature of any predicting system. Such systems prescribe probable scenarios but cannot give future certainties. In general, vulnerability rating schemes give the most likely probability of future events based on average events of the past. As such, they are useful. They are easily misused by considering them indicators of what will surely happen. They are rough estimates (MacLean 1982) of what may happen assuming that defoliation patterns of a budworm outbreak occur throughout the area. If the forests of a management unit are inundated by moths or on the other hand, the outbreak duration is shortened for some reason then the prediction of damage will be different from the reality.

A third reason why the V.I. in Newfoundland may not have been as well correlated as those on the mainland is that Newfoundland's forests are largely northern fir-spruce forests with relatively low volume of hardwoods or other non-host tree species compared to mainland forests. This tends towards higher volume per ha of host species and therefore higher V.I. Therefore, Newfoundland forests will tend to have higher V.I.'s than many forested areas on the mainland.

This vulnerability rating system should be viewed as an estimate of potential damage by budworm and not as a certainty of future events. Furthermore, it is an ongoing process that needs to be

recalculated as forest inventories change. At present, the rating system reflects the vulnerability of forests to budworm as best as our understanding of the budworm-forest interaction allows it.

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APPENDIX I. Vulnerability Index of Forest Management Units in Newfoundland based on volume of fir, spruce, maturity of fir and climate rating.

Forest management unit	Volume (m^3) (x 000)		Area Prod. For. (ha)	Vol./ha Fir	Rating	Vol./ha Spruce	Rating	Maturity of Fir 60 yrs. plus	Rating	Climatic index	Vulnerability index
	fir	spruce									
1	3 176	794	125 500	25	4	6	1	51	3	0	12
2	4 371	5 995	145 540	30	5	41	6	64	3	4	25
3	1 350	760	53 548	25	4	14	3	51	3	0	12
4	1106	3029	74 680	15	3	41	6	50	3	8	17
5	1 581	6 892	214 160	7	2	32	5	50	3	8	14
6	2 911	7 106	161 880	18	3	44	7	38	2	8	14
7	2 961	3 143	110 710	27	4	28	5	63	3	8	20
8	1 998	7 609	162 160	12	2	47	7	37	3	8	12
9	6 906	11 926	328 790	21	4	36	6	53	3	8	20
10	966	5 096	105 730	9	2	48	7	29	2	8	12
11	1 120	4 768	140 170	8	2	34	5	19	1	8	11
12	3 467	6 358	162 590	21	4	39	6	30	2	8	16
13	2 457	1 297	57 410	43	7	23	4	57	3	8	33
14	12 400	3 569	281 110	44	7	13	2	51	3	8	31
15	13 400	3 890	260 530	51	8	15	3	39	2	8	27
16	12 090	5 525	215 830	56	9	26	4	75	3	0	31
17	10 258	3 889	170 250	60	9	23	4	79	3	0	31
18	8 712	2 372	145 150	60	9	24	4	79	3	0	31
19	12 295	28 599	359 690	34	5	79	10	99	3	0	25